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ABSTRACT:

High-Temperature Solid-State Nanotextured Converters for Concentrated Solar Energy

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High-temperature solar cells are possible by exploiting hybrid thermionic mechanisms, such as thermionic-thermoelectric generation, thermionic-photovoltaic conversion, and photon-enhanced thermionic emission (PETE) concept, which represent novel and attractive mechanisms for the exploitation of solar radiation, especially if concentrated, and characterized by promisingly high conversion efficiency (>50%).

Ultrashort laser pulses are able to tailor the optical properties of concentrated sunlight absorbers by maximizing solar absorption and selectivity thanks to periodic nanostructures produced on their surface [1]. Solar thermionic energy converters with nanotextured-surface absorbers already demonstrated the application feasibility with the release of the first prototypes based on nanodiamond thermionic emitters [2]. PETE converters are more advanced since they rely on the concept that engineered semiconductor photocathodes can provide very efficient electron emission, induced by hot electrons, produced by photons with sufficient energy, combined with thermionic emission, sustained by every thermalization process. Surface nanotexturing induced by ultrashort laser treatments is also able to tailor the electronic properties of semiconductors, therefore PETE cathodes can be drastically enhanced in terms of photosensitivity even to sub-bandgap radiation.

Especially in the case of black diamond, surface nanotexturing combined with surface-hydrogenation, aimed at achieving negative electron affinity conditions, is proposed as a radically new and potentially effective PETE cathode up to temperatures of 700 °C [3]. CVD diamond is transparent to solar radiation due to its wide bandgap, consequently, black diamond technology was developed to drastically increase its absorption coefficient (solar absorptance >99% in the double-textured samples [4]) and photogeneration capability under sunlight irradiation. A final p-type/intrinsic structure merges the technologies of surface texturing by fs-laser, boron-implantation for the formation of buried p-type layer, and laser-induced graphitic microchannels [5], to form an innovative defect-engineered black diamond cathode for the conversion of

concentrated solar radiation. Results under a high-flux solar simulator will be reported and discussed by demonstrating for the first time the PETE effect at temperatures from 300 to 500 °C.

But there is more. Nanodiamond emitters deposited on surface-nanotextured silicon can be a viable and cost-effective solution for PETE converters [6], as well as perovskite-based PETE cathodes under development for low-radiation-flux solar concentrators.

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